



بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

In the Name of Allah, the Compassionate, the Merciful.

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Run-off estimation of Kunhar River using Satellite Remote Sensing(SRS) and GIS Techniques

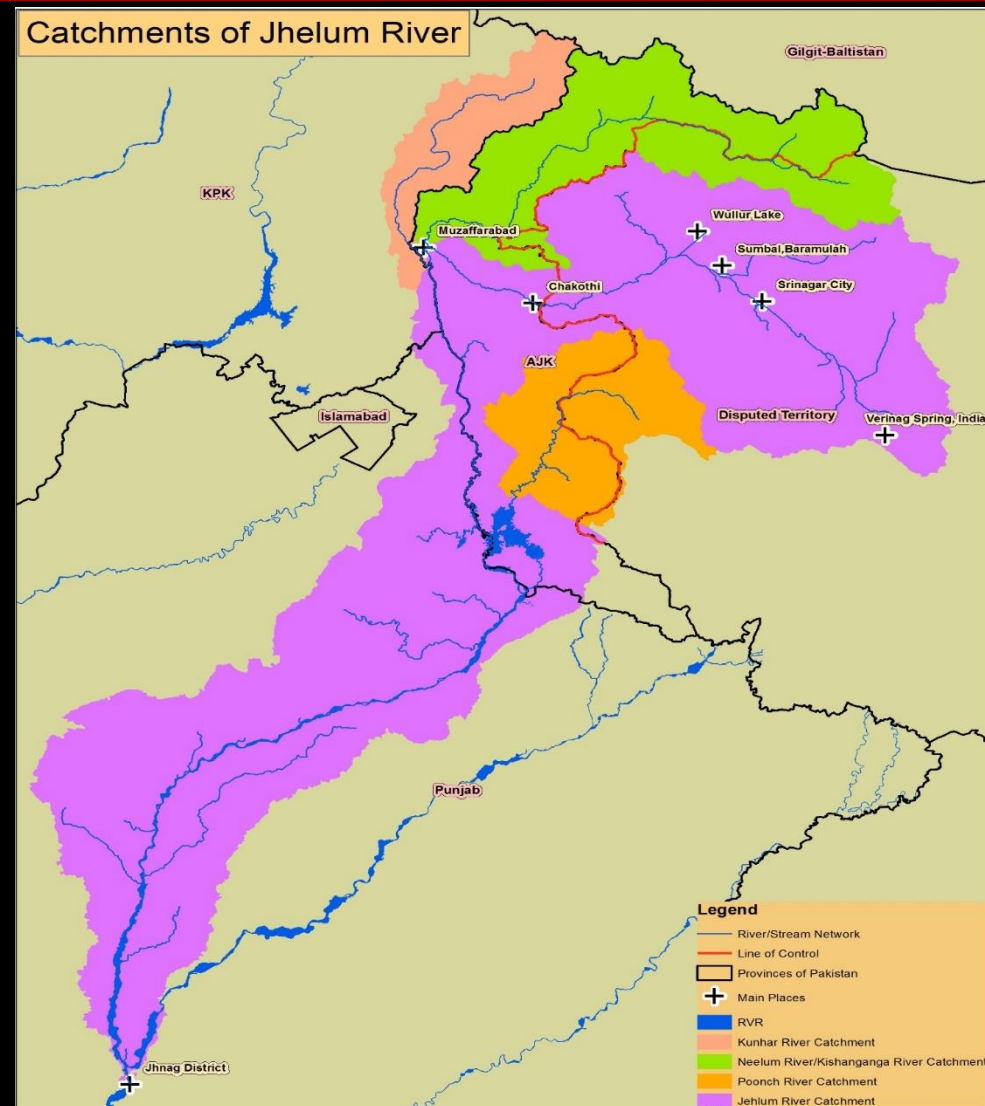


Background

- Pakistan is a country of more than 210 Million people
- Water is required for
 - Irrigation
 - Hydro energy generation and
 - Clean water drinking
- Climate change (Flooding and droughts)
- Water management plan.
- Assessment of water resources
- Catchment and Sub-Catchment Level
- Runoff estimation(Ground based Equipment's)
- Satellite Remote Sensing Methods



Study Area-Kunhar River Catchment



Reasons for Choosing this Study Area are;

- Neelum River Catchment
- Poonch River Catchment
- Jhelum River Catchment

58 % area of these catchments lie in disputed territory while 42% lie in AJK, Pakistan.

Therefore there is a strong need to manage the remaining 42% catchment water.

- The Kunhar Catchment entirely lies in Pakistan therefore ground collection of data and validation is convenient
- The Kunhar River is ideal for small to medium scale hydro energy development projects.



Data Sets

- Satellite Data

- Landsat-8 Images for Snow Cover

- Runoff/Water Discharge Data

- Average Monthly Inflow of water at Garhi Habibullah Source: WAPDA

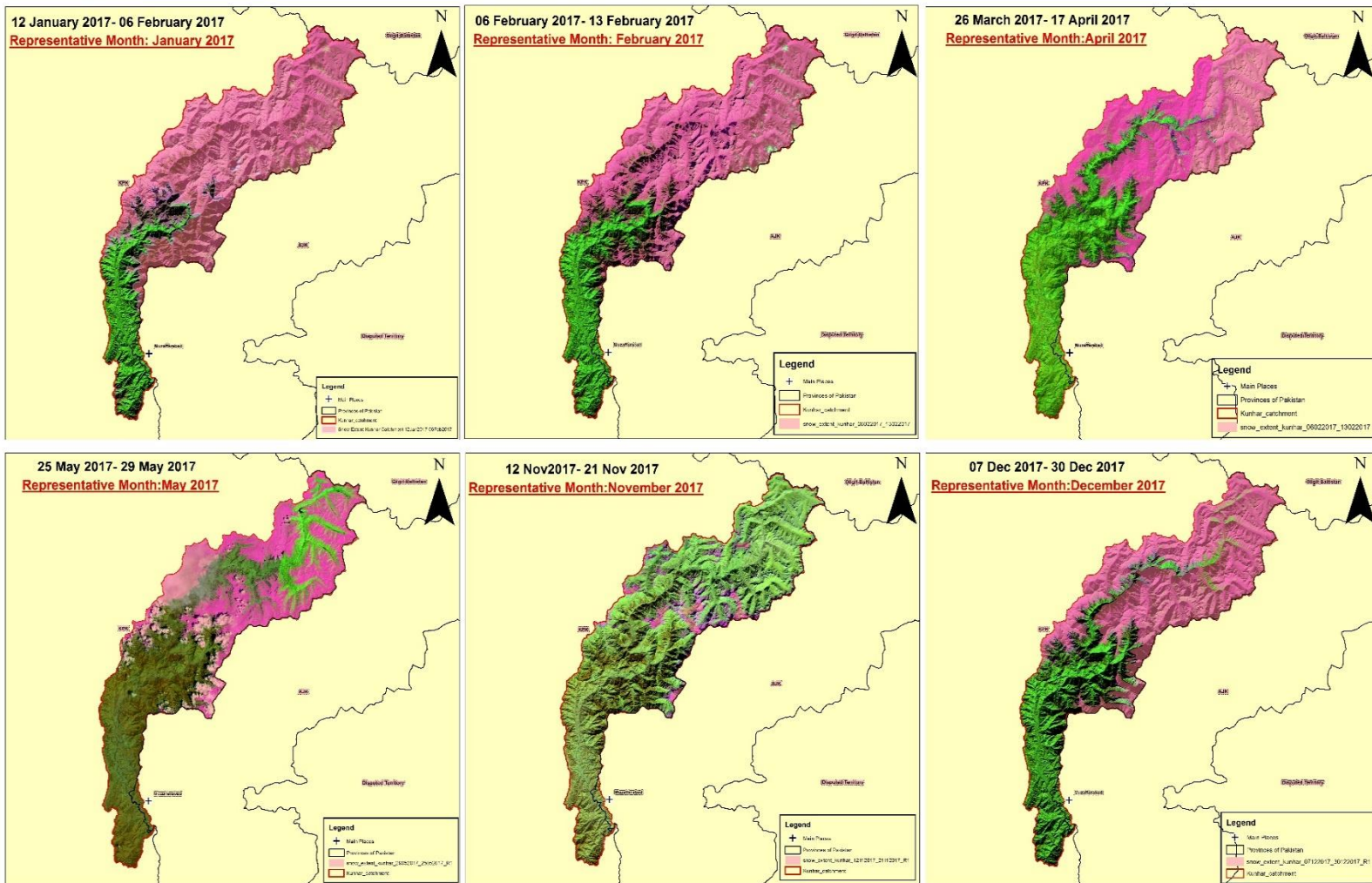
- Weather Data

- Average Monthly Temperature and Rainfall (1991-2015) Source: Worldbank Global Climate Change Portal
- Location are Gittidas, Jhalkhand, Batakundi, Paras and Garhi Habibullah



Satellite Remote Sensing -Snow Cover

Temporal Snow Cover Area of Kunhar Catchment (2017)



Month	Snow Cover(Sq.Kms)
Dec	1467.98
Jan	1947.3
Feb	1543.89
Mar	1442.47
Apr-17	1390.6
May-17	966.31
Jun-17	890.5
Jul-17	654.1
Aug-17	566.7
Sep-17	402.5
Oct-17	96.55
Nov-17	54.52

- Spectral Response of Snow at Band 5,6,4
- Extraction of Snow Cover using GIS techniques

Snow Cover For the Month of December & January (2008-2017)

Year-Dec	Snow Cover(sq.km)
2008	1547.25
2009	1401.87
2010	1440.58
2011	1581.08
2012	1465.554
2013	1361.24
2014	1524.05
2015	1444.24
2016	1428.21
2017	1467.98

Year-Jan	Snow Cover(sq.km)
2008	2287.24
2009	1845.24
2010	2344.21
2011	2154.21
2012	2200.24
2013	1855.75
2014	1998.254
2015	2405.9
2016	2022.5
2017	1947.3



Runoff and Weather Data

Monthly Average Runoff & Rainfall at Garhi Habib ullah (2008-2017) for the Month of Dec & Jan

Year	Runoff(Cusecs)-Jan	Rainfall(mm)-Jan	Runoff (Cusecs)-Dec	Rainfall(mm)-Dec
2008	63.5	75.125	70.5	17.4
2009	92.54	63.88	88.54	23.54
2010	59.05	70.189	101.54	30.24
2011	64.8	55.778	87.4	23.54
2012	66.9	66.219	89.2	24.9
2013	71.24	47.258	78.87	21.05
2014	68.4	51.478	69.54	16.24
2015	40.8	60.579	80.24	22.54
2016	65.4	58.465	91.25	26.24
2017	72.8	55.415	84.56	23.95

Monthly Average Runoff, Temperature & Rainfall at Garhi Habib ullah from January-December 2017

Month	Temp	Rainfall	Runoff
Dec	-1.3	23.95	84.56
Jan	-4.0	55.415	72.8
Feb	-2.8	79.84	352.08
Mar	1.8	71.44	572
Apr-17	6.3	74.835	718.56
May-17	9.9	55.9	936.8
Jun-17	13.6	55.535	984.4
Jul-17	15.6	90.99	270.8
Aug-17	15.1	84.81	181.2
Sep-17	12.2	48.33	77.36
Oct-17	8.0	24.78	63.76
Nov-17	2.8	20.16	49.6



Interpretations

Seasonal Classification of Kunhar River Catchment

S.No	Period	Status	Duration
1	15 Nov 2017-15 Feb 2017	Snow Accumulation	3 Months
2	15 Feb 2017-15 Jun 2017	Snow Melting	4 Months
3	15 Jun 2017- 15 Sep 2017	Rainy-Leftover Snow Melt	3 Months
4	15 Sep 2017-15 Nov 2017	No Melting/v.Low Melting	2 Months

Parameters

- Runoff
- Snow Cover
- Rainfall
- Temperature

- Snow Cover= V.Low,At places, Rainfall exists,

 - Runoff will depend primarily on Rainfall, Temperature Reduces

- Snow Cover=Max, Temperature $<0^{\circ}\text{C}$, Rainfall (Snow Cover Area ,Non Snow Cover Area)

 - Runoff will depend on Rainfall of non Snow Cover or Temperature $>0^{\circ}\text{C}$
 - Snow Cover will depend on Rainfall on Snow Cover Area or Temperature $>0^{\circ}\text{C}$
- Snow Cover=Depleting, Temperature $>0^{\circ}\text{C}$,

 - Runoff will depend on Snow Cover 70-80% and 20-30 % Rainfall of non Snow Cover & Snow Cover Area because Temperature $>0^{\circ}\text{C}$
- Rainy(Monsoon) Major portion of Snow is melted. Snow Cover=Depleting, Temperature $>$ Rising,

 - Now Runoff will depend on 30-40% on Snow Cover and 60-70% on Rainfall

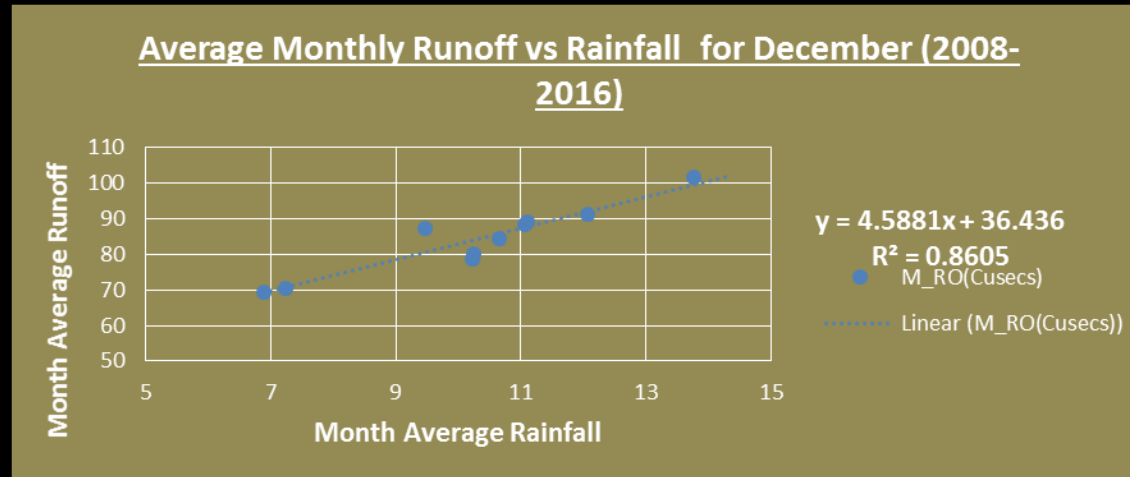


Analysis-Season-1(December)

December

1. Snow Cover=Max, Temperature <0 °C, Rainfall (Snow Cover Area ,Non Snow Cover Area)
 - Runoff will depend on Rainfall of non Snow Cover or Temperature>0 °C
 - Snow Cover will depend on Rainfall on Snow Cover Area or Temperature > 0°C
- Area of Kunhar Catchment=2646 sq.kms

Year	SC(sq.km)	RF	RF Non Snow	Variability	M_RO(Cusecs)	Cal_RO(Cusecs)	%age of Non.Snow Area	Variability%	Trend
2008	1547.25	17.4	7.225340136		70.5	69.58658308	0.415249433		
2009	1401.87	23.54	11.06833719	34.72	88.54	87.21863785	0.470192744	-53.18776666	Incr
2010	1440.58	30.24	13.77622857	19.65	101.54	99.64271431	0.455563114	-24.465205	Incr
2011	1581.08	23.54	9.474004837	-31.19	87.4	79.90368159	0.402464097	31.22932892	Decr
2012	1465.554	24.9	11.10850544	14.71	89.2	87.40293382	0.446124717	-17.25247805	Incr
2013	1361.24	21.05	10.22078534	-8.01	78.87	83.3299852	0.485547997	7.991355007	Decr
2014	1524.05	16.24	6.886042328	-32.68	69.54	68.02985081	0.424017385	32.62707217	Decr
2015	1444.24	22.54	10.23721481	32.68	80.24	83.40536529	0.454179894	-48.66616159	Incr
2016	1428.21	26.24	12.07664762	15.24	91.25	91.84486694	0.460238095	-17.96809814	Incr
2017	1467.98	23.95	10.66272827	-11.68	84.56	85.35766357	0.445207861	11.70787949	Decr





Results-Season-1 for December

Year	SC(sq.km)	RF	RF Non Snow	Variability	M_RO(Cusecs)	Cal_RO(Cusecs)	%age of Non.Snow Area	Variability%	Trend
2008	1547.25	17.4	7.225340136		70.5	69.58658308	0.415249433		
2009	1401.87	23.54	11.06833719	34.72	88.54	87.21863785	0.470192744	-53.18776666	Incr
2010	1440.58	30.24	13.77622857	19.65	101.54	99.64271431	0.455563114	-24.465205	Incr
2011	1581.08	23.54	9.474004837	-31.19	87.4	79.90368159	0.402464097	31.22932892	Decr
2012	1465.554	24.9	11.10850544	14.71	89.2	87.40293382	0.446124717	-17.25247805	Incr
2013	1361.24	21.05	10.22078534	-8.01	78.87	83.3299852	0.485547997	7.991355007	Decr
2014	1524.05	16.24	6.886042328	-32.68	69.54	68.02985081	0.424017385	32.62707217	Decr
2015	1444.24	22.54	10.23721481	32.68	80.24	83.40536529	0.454179894	-48.66616159	Incr
2016	1428.21	26.24	12.07664762	15.24	91.25	91.84486694	0.460238095	-17.96809814	Incr
2017	1467.98	23.95	10.66272827	-11.68	84.56	85.35766357	0.445207861	11.70787949	Decr
2018			14.36482752			102.3432652	1		Incr
2019			17.18751613			115.2940428	1		Incr
2020			11.82672985			90.69821923	1		Decr
2021			13.56644181			98.68019168	1		Incr
2022			12.47976982			93.69443192	1		Decr
2023			8.401381045			74.98237637	1		Decr
2024			11.14695237			87.57933217	1		Incr
2025			12.84574791			95.37357599	1		Incr
2026			11.34536456			88.48966712	1		Decr
							1		

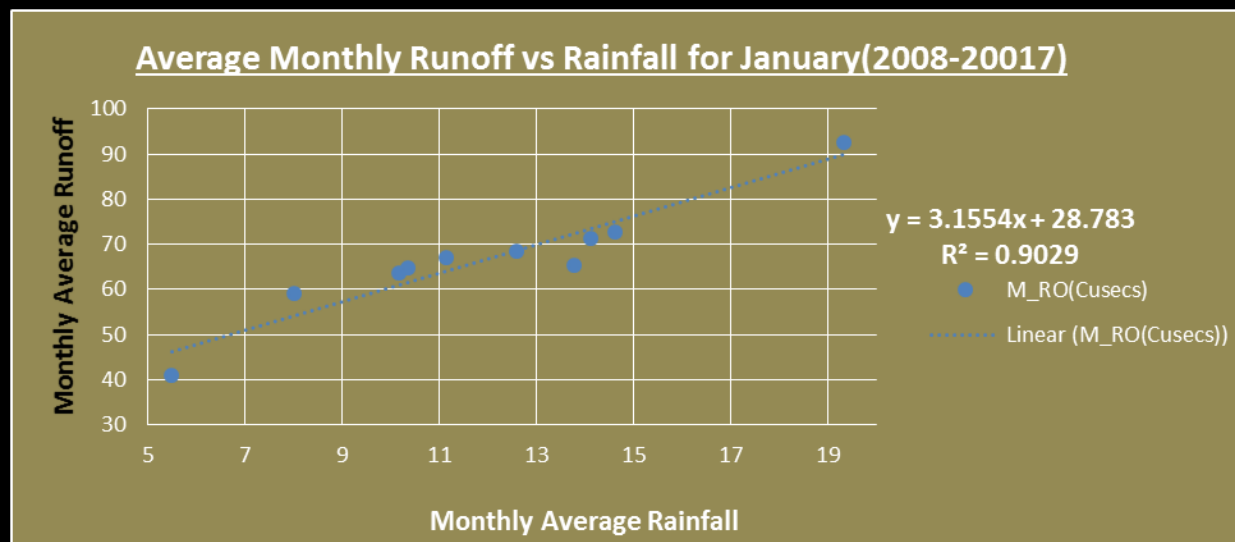
$m=4.5881, c=36.436, Y=m(X)+c, x=RF \text{ on Non.Snow Cover Area or where } T>0 \text{ } ^\circ\text{C}$



Analysis-Season-1(January)

January

% RF on Snow Area	Variability%	Trend for RF on Snow Area	Year	SC(sq.km)	RF	RF Non Snow	Variability%	M_RO(Cusecs)	Cal_RO(Cusecs)	%age of Non.Snow Area	%age of Snow Area	Trend for RF Non Snow
64.93911754			2008	2287.24	75.125	10.18588246		63.5	60.92353353	0.13558579	0.86441421	
44.54797098	-31.4	Decr	2009	1845.24	63.88	19.33202902	47.3	92.54	89.78328439	0.302630385	0.697369615	Incr
62.18358114	28.36	Incr	2010	2344.21	70.189	8.005418862	-58.58	59.05	54.04329868	0.114055178	0.885944822	Decr
45.41100732	-26.97	Decr	2011	2154.21	55.778	10.36699268	22.73	64.8	61.49500869	0.185861678	0.814138322	Incr
55.06337587	17.52	Incr	2012	2200.24	66.219	11.15562413	7.07	66.9	63.98345637	0.168465608	0.831534392	Incr
33.144400359	-39.81	Decr	2013	1855.75	47.258	14.11399641	20.94	71.24	73.31830427	0.298658352	0.701341648	Incr
38.87608443	14.74	Incr	2014	1998.254	51.478	12.60191557	-10.7	68.4	68.54708438	0.244801965	0.755198035	Decr
55.08201667	29.42	Incr	2015	2405.9	60.579	5.496983333	-56.42	40.8	46.12818121	0.090740741	0.909259259	Decr
44.68838341	-18.88	Decr	2016	2022.5	58.465	13.77661659	60.08	65.4	72.25373599	0.2356387	0.7643613	Incr
40.7821729	-8.72	Decr	2017	1947.3	55.415	14.6328271	5.87	72.8	74.95542262	0.264058957	0.735941043	Incr





Results-Season-1 for January

% RF on Snow Area	Variability%	Trend for RF on Snow Area	Year	SC(sq.km)	RF	RF Non Snow	Variability%	M_RO(Cusecs)	Cal_RO(Cusecs)	%age of Non.Snow Area	%age of Snow Area	Trend for RF Non Snow
64.93911754			2008	2287.24	75.125	10.18588246		63.5	60.92353353	0.13558579	0.86441421	
44.54797098	-31.4	Decr	2009	1845.24	63.88	19.33202902	47.3	92.54	89.78328439	0.302630385	0.697369615	Incr
62.18358114	28.36	Incr	2010	2344.21	70.189	8.005418862	-58.58	59.05	54.04329868	0.114055178	0.885944822	Decr
45.41100732	-26.97	Decr	2011	2154.21	55.778	10.36699268	22.73	64.8	61.49500869	0.185861678	0.814138322	Incr
55.06337587	17.52	Incr	2012	2200.24	66.219	11.15562413	7.07	66.9	63.98345637	0.168465608	0.831534392	Incr
33.14400359	-39.81	Decr	2013	1855.75	47.258	14.11399641	20.94	71.24	73.31830427	0.298658352	0.701341648	Incr
38.87608443	14.74	Incr	2014	1998.254	51.478	12.60191557	-10.7	68.4	68.54708438	0.244801965	0.755198035	Decr
55.08201667	29.42	Incr	2015	2405.9	60.579	5.496983333	-56.42	40.8	46.12818121	0.090740741	0.909259259	Decr
44.68838341	-18.88	Decr	2016	2022.5	58.465	13.77661659	60.08	65.4	72.25373599	0.2356387	0.7643613	Incr
40.7821729	-8.72	Decr	2017	1947.3	55.415	14.6328271	5.87	72.8	74.95542262	0.264058957	0.735941043	Incr
27.97657061		Decr	2018	1765.63488		21.55415431			96.79497852			Incr
35.91072604		Incr	2019	1897.40533		8.927730717			56.9535615			Decr
26.22560322		Decr	2020	1736.55481		10.95700391			63.35673013			Incr
30.82032891		Incr	2021	1812.86402		11.73166409			65.80109286			Incr
18.55075597		Decr	2022	1609.09095		14.18827454			73.5526815			Incr
21.2851374		Incr	2023	1654.50356		12.67012917			68.76232558			Decr
27.54722482		Incr	2024	1758.50431		5.521642292			46.20599009			Decr
22.34630878		Decr	2025	1672.12749		8.839044981			56.67372253			Incr
20.39771065		Decr	2026	1639.76517		9.357896921			58.31090794			Incr

$Y=m(X)+c$, $x=RF$ on Non.Snow Cover Area or where $T>0$ °C

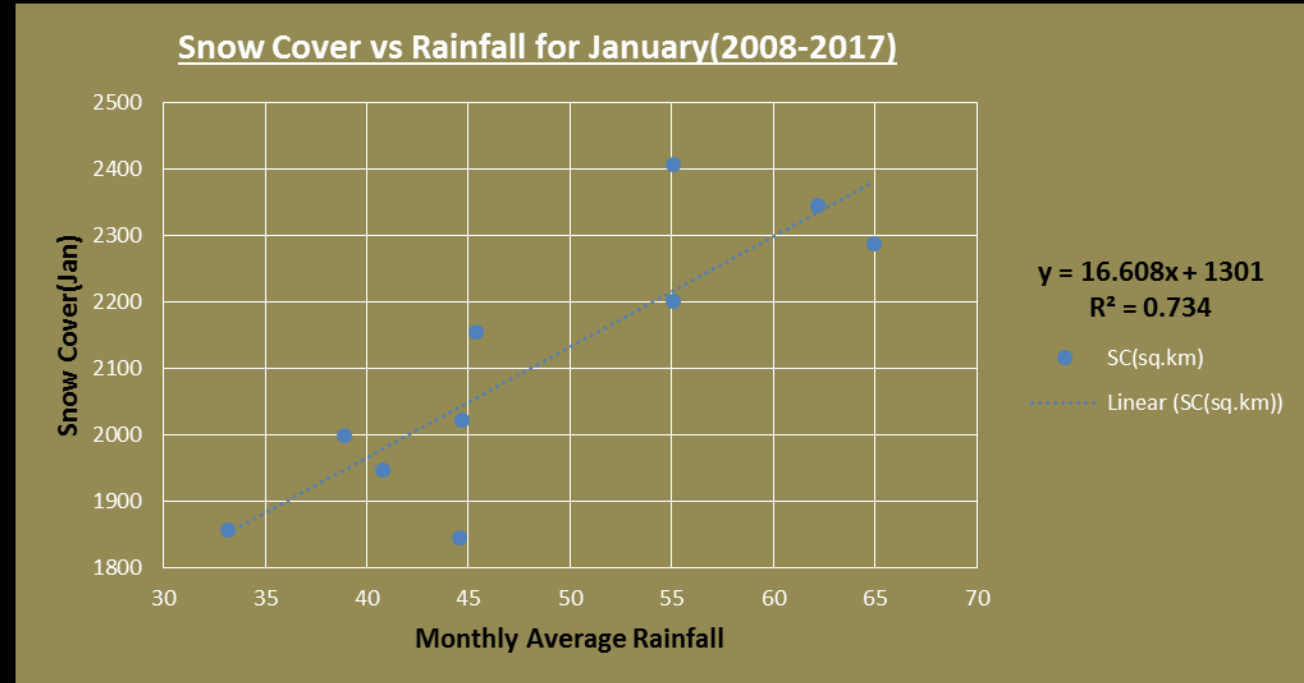


Results-Season-1 for January for Snow Cover

Snow Cover will depend on Rainfall on Snow Cover Area or Temperature $> 0^{\circ}\text{C}$

$$m=16.608, c=1301$$

$$Y=m(X)+c, x=\text{RF on Snow Cover Area or where } T < 0^{\circ}\text{C}$$

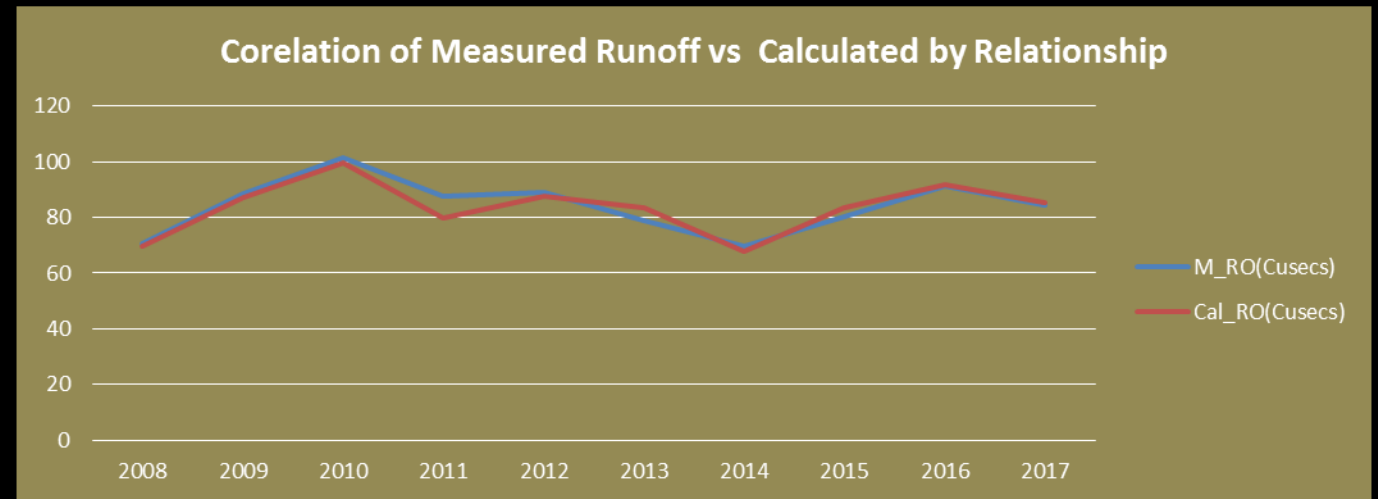




Conclusions

- Runoff estimation can be done on seasonal basis because snow cover, Temperature and Rainfall behavior changes season to season and dependency of one variable to others also varies seasonally.
- The Runoff simulation results for this relationship has shown significant correlation with the measured amount of runoff.

Average Runoff Measured 2008-2017=84.5
Average Runoff Simulated 2018-2026=94.2 Cusecs





Way Forward

- Hypsometric analysis should be done for each Class of Season
- Snow Cover for each hypsometric Zone be calculated
- Also the temperature ,rainfall data for each hypsometric zone be taken separately
- Landsat 8 thermal band must be tested for each hypsometric zone and relationship should be established for snow cover volume using ground based snow thickness data
- Thermal band based snow volume estimation
- SUPARCO,PMD and WAPDA should collaboratively work on Runoff estimation of the catchments



Thank you

Questions